ITIC-410 USA   REV.A   <u>PATENT</u>

SYSTEM AND METHOD FOR COMBINING
MULTIPLE SATELLITE CHANNELS INTO
A VIRTUAL COMPOSITE CHANNEL

<u>CROSS-REFERENCE TO RELATED APPLICATIONS</u>

5   The present application is a continuation-in-part of Application No. 09/243,910

filed February 3, 1999, and claims priority to Provisional Application No. 60/142,179

filed July 1, 1999.

<u>BACKGROUND OF THE INVENTION</u>

10   The invention relates to satellite communications systems generally, and more

particularly to satellite communication systems which divide the transmitted signal,

either in power or in content, to be synchronized and recombined in the receiving

terminal. This concept applies readily to broadcast applications, but it is not so limited.

The satellite industry has experienced a progression of performance

15   enhancements evidenced by increased transmit power capability of satellite

transponders, improved low-noise amplifier (LNA) characteristics, and smaller

receiving antennas. In satellite systems with a large number of receiving stations, it is

particularly important to reduce the cost of each receiving unit and to design a system

with a small receiving antenna to meet installation and aesthetic requirements. The

20   need for a small receiving antenna has motivated an increase in transponder power

output in order to maintain an acceptable signal-to-noise ratio (SNR) with the smaller

antenna. As satellite users move from lower power transponders to higher power

transponders, falling demand for the lower power transponders reduces the cost of their

use. Receiving a signal from a lower power transponder with the smaller receiving

25   antenna size produces a received power at the LNA too low to maintain SNR

requirements. The present invention permits the receiver to combine received signals

from a plurality of transponders, possibly located on a plurality of satellites to enable

again the use of lower power transponders, but with small receiving terminal antennas.

SUMMARY OF THE INVENTION

A satellite communications system includes a transmitting station that directs information-carrying signals toward an orbiting satellite, which receives the signals and in turn retransmits the signals on a different frequency band toward a plurality of

5 receiving terminals. The satellite contains a transponder which receives signals as a broad band of frequencies and retransmits them on another set of frequencies of equal bandwidth but shifted to another location in the spectrum.

The present invention has as its object a satellite communications system including a transmitting facility that divides the signal into a plurality of subchannels

10 directed toward a plurality of transponders located on one or more satellites and a receiving terminal that receives the subchannels, time-synchronizes the subchannels, and combines them into a faithful replica of the original composite signal. The division of the signal into subchannels is carried out by one of two methods. In a first division method, the source signal is replicated across the plurality of transponders. Hereinafter

15 the first division method is referred to as power-division. In a second division method, the content of the source signal is represented by a set of distinct subsignals, each of which subsignals contains less information as the original signal, but said distinct subsignals can be conveniently recombined in the receiver to reconstruct the original signal satisfactorily. Hereinafter this second division method is referred to as content-

20 division.

In a system using power-division to create subchannels, the originating transmitter directs more than one identical signal to a plurality of transponders, possibly located on a plurality of satellites. In said system, transponders retransmit and the receiving antenna system conducts all of the aforementioned signals into the receiving

25 system. The receiving terminal provides means of time-synchronizing the plurality of received signals, adjusts the relative power level of the plurality of received signals to be approximately equal, and combines the signals into a composite via a signal adding process. Each of the signals added contains both an information component and a random noise component, such noise having been introduced primarily in the first

30 amplifier of the receiver, typically a low-noise block converter (LNB). Those skilled in

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the art know that the information component of each signal will be statistically

correlated, but the noise components will be statistically uncorrelated, both to each

other and to the information component. Thus the information components will add

linearly into the composite signal, that is in proportion to their number. The power in

5   the information component of the composite signal will then be in proportion to the

square of the number of received signals being added together. In contrast, the power in

the noise component of the composite signal will be in proportion to the number of

received signals added together. Thus the SNR of the composite signal is improved

over the SNR of the individual subchannel signals by a factor of N in power, where N is

10   the number of channels added together to form the composite signal. The foregoing

discussion assumes that the signal levels and noise levels in each of the subchannel

signals is identical. In a real system, transmission characteristics will vary slightly

between subchannels, signal and noise levels being slightly different between

subchannels, resulting in an SNR improvement ratio somewhat less than the factor of N

15   described above. In any case, the receiver may require automatic means of adjusting

the power of each of the signals to be added at the combining point so as to be

approximately equal to each other in level.

In a system using content-division to create subchannels, the originating

transmitter directs distinct subsignals toward the plurality of transponders, the

20   subsignals being created in such a way as to permit convenient reconstruction of the

original signal at the receiving terminal. In an exemplary analog system, the original

signal can be divided into sub-band signals using a filter-bank process. If the filters

used satisfy quadraturemirror properties, the subsignals can be added directly to

reproduce the original signal without phase distortion at the boundary frequencies. If

25   the analog signal contains a strong periodic timing component (as does a television

signal), this periodic timing component can be separated from the remainder of the

signal before dividing the signal into sub-band components. Said timing component

could then be added back to each of the sub-band components to produce subchannel

signals with different frequency components, but common timing information. This

strategy naturally provides timing information useful to facilitate the necessary time-resynchronizing process in the receiver.

As above, in a system using content-division to create subchannels, the originating transmitter directs distinct subsignals toward the plurality of transponders, the subsignals; being created in such a way as to permit convenient reconstruction of the original signal at the receiving terminal. In an exemplary digital system, the original binary signal can be divided into subchannel digital signals, each of which has a bit rate less than the original digital signal. The original digital signal can be divided into subchannel digital signals in any number of ways. Two simple exemplary digital subchannel strategies are as follows. A first exemplary digital subchannel strategy is to direct each successive bit into each subchannel sequentially. A second exemplary digital subchannel strategy is to direct each fixed-size block of bits in the original signal to each successive subchannel sequentially. This second exemplary strategy fits well with digital source signals that are organized in a fixed-blocksize structure in the original signal as in Digital Video Broadcast (DVB) for example.

In the case that a plurality of satellites is used to conduct a set of subchannels from a transmitting station to a given receiving terminal, each subchannel will generally experience a different propagation delay. The instant invention provides means to determine the amount of time to delay each subchannel in order to combine them synchronously. The delay required for each received subchannel will in the general case differ. The present invention provides additional means to implement the aforedetermined delay for each subchannel independently.

The receiving terminal system, when activated for a particular virtual channel, determines the relative delay between the subchannel signals arriving at the receiver. This could be accomplished by correlating the subchannel signals with each other at all possible delays expected in a particular implementation of the system. As this process is very time consuming and source signal dependent, it is therefore subject to false synchronization and possible failure to synchronize at all, particularly if the source signal does not contain enough timing information. The present invention solves this

problem by transmitting a timing signal along with the original signal. Some sources may by their nature guarantee adequate timing information to facilitate reliable synchronization.

5   The timing signal described arrives at the receiving terminal via a plurality of propagation paths, each experiencing a different delay, the timing signal is being added to the virtual satellite system in such a way so as to be separable from the original signal on each subchannel. The receiving terminal then correlates timing signals arriving on different subchannels; to determine the amount of relative propagation delay. All subchannel signals contain common timing information to facilitate the correlation

10   process. This guarantees that the subchannels can be processed and compared in a known way to determine relative propagation delay.

The timing signal if required for synchronization can be added to the virtual satellite channel using one of two exemplary methods, but the instant invention is not so limited. A first exemplary method requires that a narrow bandwidth signal be

15   transmitted across each satellite in the virtual channel. The narrow band signal requires a small allocation of the available spectrum, but provides a dedicated timing signal on each satellite actively carrying virtual satellite channels. The narrow band timing signal provides propagation delay information to virtual channel receiving terminals having one or more subchannels on the satellite. The timing signal could consist of one or

20   more of the following exemplary signals, but the instant invention is not so limited. A first exemplary signal is a carrier modulated digitally by a binary pseudorandom noise sequence. A second exemplary signal is a periodic pulse. The pulse could be time-dispersed prior to transmission to create a signal with improved peak to average waveform properties. The receiving terminal in this example would reverse the

25   time-dispersal process to recover a narrow-time pulse. The time period of either exemplary signal above described, after which the signal repeats, would be longer than twice the greatest expected delay difference between subchannels, thus facilitating unambiguous determination of propagation delay.

A second exemplary method of incorporating a timing signal in the virtual satellite system consists of adding a spread spectrum component to each of the information-bearing subchannels in the system, and within the bandwidth of each subchannel. The magnitude of the spread spectrum timing component is much lower

5   than the information signal so as not to reduce the performance of the normal receiver demodulation process. The spread spectrum signal is then de-spread in the receiving terminal, thereby increasing its magnitude above that of the information content. The increase in signal level is proportional to the processing gain. This process facilitates delay synchronization in the receiving terminal and has two advantages. A first

10   advantage is that the second exemplary method does not increase the bandwidth requirements of the virtual channel to accommodate a timing signal. A second advantage is that the full bandwidth of the information channel is available to the timing signal resulting in high resolution relative delay estimation.

DESCRIPTION OF THE DRAWINGS

15   Fig. 1 is a schematic and block diagram illustrating the present invention.

Fig 2 is a schematic and circuit block diagram of one embodiment of the present invention.

Fig. 3 is a schematic and circuit block diagram of another embodiment of the present invention.

20   Fig. 4 is a schematic and circuit block diagram of another embodiment of the present invention.

Fig. 5 is a schematic and circuit block diagram of another embodiment of the present invention.

Fig. 6 is a schematic and circuit block diagram of a multiple beam antenna

25   embodiment of the present invention.

DESCRIPTION OF THE INVENTION

Referring now to the drawings in which like reference numerals indicate like or corresponding elements over the several views, FIG. 1 shows an overview of the satellite communications system consisting of subsystems 12, 10, 16. Original signal

22 feeds subchannel divider 24 which separates the signal into a plurality of numbered subsignals. The exemplary system of FIG. 1 shows the number of subsignals to be four, but the present invention is not so limited. Subchannel divider 24 creates the subsignals by dividing original signal 22 employing one of two methods. A first method divides

5   the signal on the basis of power. In this first method all the subchannel signals emerging from subchannel divider 24 are identical. A second method divides the signal on the basis of content. In this second method, each subchannel signal carries at least some information that is not carried by the other subchannels. The information content may be mutually exclusive or may overlap between subchannels, but in any case the

10   subchannel signals under the second divider method are not identical as in the first method. Each subchannel signal feeds an uplink transmitter 26a-26d, each of which uplink transmitters feeds a separate antenna 28a-28d, directing radio frequency energy toward a plurality of orbiting satellites 14a-14d via propagation paths 18a-18d. Uplink transmitters 26a-26d add timing signal 23 to the signal to be transmitted either on a

15   separate frequency allocation or in the bandwidth of the information-bearing carrier.

The exemplary system of FIG. 1 shows the number of satellites used by the system to be four, but the instant invention is not so limited. Each satellite 14a-14d receives a band of frequencies, amplifies the signals received in that band, and retransmits the band at a different location in the spectrum. Each of said satellites has a

20   transmitting antenna pattern that includes receiving terminal system 16. Propagation paths 20a-20d from each satellite 14a-14d to representative receiving terminal 16 carry radio frequency energy from satellites 14a-14d to the receiving terminal system 16. It should be understood that although FIG. 1 depicts each uplink signal being carried by a different satellite, the present invention is not so limited. For example, transponders of

25   satellites 14a, 14b could be collocated on the same satellite. In this case, uplink transmitters 26a, 26b and uplink antenna systems 28a, 28b could be combined, in addition to satellites 14a, 14b representing the same satellite. Propagation paths 18a, 20a, 18b, 20b in this case would be combined into single uplink and downlink propagation paths. Receiving terminal system 16 incorporates one of two antenna

methods. A first method includes a plurality of antenna components to receive the plurality of satellite signals 20a-20d. A second method incorporates a multiple beam antenna. The exemplary system of FIG. 1 uses multiple beam antenna 30, but the present invention is not so limited. In either of the aforementioned receiving terminal

5   antenna methods, the antenna subsystem produces a plurality of output signals corresponding to the subchannel signals emerging from subchannel divider 24 in uplink system 12. In the exemplary system of FIG. 1, each of the numbered signals emerging from multiple beam antenna 30 correspond to similarly numbered signals emitted by subchannel divider 24. This signal identity remains true whether satellites 14a, 14b of

10   FIG. 1 are distinct or represent the same satellite as indicated in the foregoing description. The subchannel signals emitted by multiple beam antenna 30 feed a plurality of tuners 32 which then drive a plurality of demodulators 34. A signal emerging from one of the demodulators 34 then represents a version of the corresponding output of subchannel divider 24, but delayed in time in proportion to the

15   sum of the lengths of the corresponding uplink and downlink propagation paths 18 and 20. In receiving terminal 16, delay component 36 further delays first-arriving signals such that all the subchannel components arrive at subchannel combiner 38 at nearly the same time. Said combiner 38 produces a reconstruction 40 of original signal 22. The method used in subchannel combiner 38 is consistent with and corresponds to the

20   method used to divide original signal 22 in subchannel divider 24.

(DIGITAL CONTENT-DIVISION)

The instant invention uses one of four methods to perform the dividing and combining operations of subchannel divider 24 and subchannel combiner 40. In each of

25   said methods, subchannel divider 24 of FIG. 1 feeds a plurality of uplink transmitters 26a-26d, but the signals emerging from subchannel divider 24 are different in nature depending of the dividing and combining method used. In a first dividing and combining method, original signal 22 is digital. In said first method, subchannel divider 24 divides said digital signal into lower data rate subchannel signals with binary content

that contains at least some mutually exclusive information. The division could be on a

sequential bit-by-bit basis, could be on a sequential frame-by-frame basis, and may or

may not relate to possible framing in the original digital signal (e.g. DVB transport).

The exemplary receiving terminal 16 of FIG. 2 depicts a two-subchannel digital

5   receiving system where the radio frequency carriers feeding the demodulators 36a and

36b are quaternary phase shift keying (QPSK) modulated signals, but the present

invention is not so limited. Said figure further indicates the use of a multiple beam

antenna 30, but the present invention is not so limited. Referring again to FIG. 2,

multiple beam antenna 30 emits first and second signals into first and second tuners 32a

10   and 32b. Each tuner shifts a band of higher frequencies to a band of lower frequencies

of equal bandwidth such that receiver controller 42 sets the center frequency of the

higher band, but the lower band is fixed. Tuners 32a, 32b emit QPSK modulated

signals at a frequency that the QPSK demodulators 36a, 36b expect to receive. As there

are two subchannels in the example of FIG. 2, the data rate of the binary information

15   contained in these QPSK signals is approximately half the data rate of original signal

22. The respective outputs of QPSK demodulators 36a, 36b emit signals to bit detectors

38a, 38b which in turn produce streams of binary data corresponding to the subchannel

division in uplink system 12. Delay operators synchronize the data streams by

introducing delay in the first-arriving binary stream such that there is a minimum of

20   relative delay between the respective delay operator outputs. Digital content combiner

48 reverses the content division process of subchannel divider 24 so as to produce at its

output a faithful delayed replica 50 of original digital signal 22. Receiver controller 42

of FIG. 2 responds to user input (not depicted) to select the transponders 14 to combine,

subsequently emitting control signals to multiple beam antenna 30 to direct its antenna

25   patterns toward the satellites containing selected transponders 14. Receiver controller

42 also selects each tuner frequency consistent with the signals emitted from the

selected transponder. Receiver controller 42 further processes information from timing

signal correlator 44 to determine the correct setting of delays 40a, 40b. Timing signal

correlator 44 receives and time correlates tuner outputs 34. For a system with more

than two subchannels, correlator 44 processes tuner outputs in pairs to determine relative delay between subchannels. Nonvolatile memory 46 contains parameters regarding the user-selected transponders to enable the correct setting of multiple beam antenna 30 and tuners 32.

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(DIGITAL POWER-DIVISION)

The instant invention can use a second method for transporting a digital signal across a virtual satellite channel. Referring to FIG. 3 which depicts an example of said second method which combines delayed demodulator outputs from identical subchannels as described previously as power combining. Under the direction of receiver controller 42, multiple beam antenna 30 emits signals to tuners 32a, 32b which translate variable transponder bands into a fixed band of frequencies expected by the QPSK demodulators 54. FIG. 3 depicts a receiving terminal using a multiple beam antenna, but the present invention is not so limited. FIG. 3 further depicts a receiving terminal with two subchannels, but the instant invention is not limited to two subchannels. The figure in addition shows the use of a QPSK modulation scheme, but the instant invention is not so limited. Subchannel signals 52 emitted by tuners 32 contain identical digital information transmitted at the full rate of original signal 22. QPSK demodulators 54 produce soft decision outputs I_A and Q_A for each subchannel. Since the total propagation delay for each subchannel is in general different, first arriving soft decisions must be delayed in time by an amount such that soft decisions emitted by delays 56 emerge with nearly zero relative delay between subchannels. Delays 56 digitize the analog soft decisions produced by demodulators 54, placing digitized results in a first-in first-out (FIFO) buffer. Receiver controller 42 controls the amount of time delay in delays 56 with input from timing signal processor 44 and digital correlator 58. Timing signal processor 44 analyzes input from tuner outputs 52 to determine the relative time delay between subchannels. For systems using more than two subchannels, the timing signal processor would process subchannel tuner outputs in pairs. Since the subchannels of FIG. 3 result from use of an uplink system 12 using

power division, delay outputs IB and QB from delays 56a, 56b are correlated. This enables digital correlator 58 to compare digitized soft decisions between subchannels and provide additional information to receiver controller 42 about relative subchannel delay at the bit level. Digital power combiner 66 processes synchronized I and Q soft

5   decisions from all subchannels to produce a single I and Q decision 68 for every set of soft decisions presented. For the case of QPSK modulation, each final decision from combiner 66 produces two bits in digital output 68.

       (ANALOG DIVISION)

10   A third method for dividing and combining the original signal address the case that original signal 22 is analog in nature. Referring to FIG. 4, receiver controller 42 directs multiple beam antenna 30 to point to selected transponder signals and directs tuners 32a, 32b to translate said transponder frequencies to a fixed band of frequencies expected by demodulators 70a, 70b. The exemplary system of FIG. 4 divides the signal

15   into two subchannels, but the instant invention is not so limited. Demodulators 70a, 70b produce analog outputs signals which are faithful replicas of the subchannel signals produced by subchannel divider 24 in the uplink system 12. Said analog signal outputs in general experience relative delay due to differing lengths of total propagation paths when using transponders on different satellites. Under direction of receiver controller

20   42, analog delays 72 add delay to first-arriving subchannel signals so as to create outputs of analog delays 72 which arrive at analog combiner 80 with near zero relative delay. Analog delays 72 consist of a high quality analog-to-digital converter (A/D), a FIFO buffer, and a digital-to-analog (D/A) converter. Each of delays 72 creates a time delay in proportion the instant size of the FIFO buffer contained therein. Delays 72

25   present output signals to analog combiner 80 which represent faithful replicas of the subchannel signals produced by subchannel divider 24 in the uplink system 12. These signals differ from outputs of demodulators 70 in that they are now time synchronized. FIG. 4 represents both signal division strategies, power division and content-division. In the first case of power-divided subchannel signals, inputs to analog combiner 80

represent identical signals, differing only in distortion and noise added by satellite transport. In a second case, time-synchronized content-divided subchannel signals arrive at analog combiner 80. Analog combiner 80 creates output 82 most likely by a simple addition process, but is not so limited. In addition to producing combined output

5   signal 82, analog combiner 80 optionally provides a measure of time synchronization to receiver controller 42 to improve the accuracy of time alignment by controller 42. As in first and second digital divider-combiner methods, timing signal correlator 44 provides relative subchannel delay informat:_n to receiver controller 42, which together with further optional delay information from analog combiner 80 provides receiver controller

10   80 with a basis to create estimates of relative delay between subchannels; which in turn affects the setting of delays 72.

(MUX DIVISION)

A fourth method for dividing the original signal applies specifically to digital signals wherein the signal to be divided consists of a combination of a plurality of

15   individual program streams as in a DVB Multiplex (MUX). As in the three previously described methods, subchannel divider 24 of FIG. 1 represents the signal dividing process. In this method, subchannel divider 24 splits the multiple signal into subsignals, placing information bits associated with any particular program stream entirely in the same subchannel. This requires a remultiplexing operation at the uplink facility but

20   eliminates the need to recombine multiple substreams at the receiving terminal. The required receiver is shown in FIG. 5 which depicts a single tuner and demodulator but requires multiple beam antenna 30, or multiple antennas, as the totality of signals in the service provided may necessarily pass through a plurality of satellites since the division process substantially increases the total satellite bandwidth requirement. The receiver

25   block diagram is simplified since there is no requirement to recombine subchannels in this method.

(INTERNET MULTIBEAM ANTENNA)

FIG. 6 provides more details of an exemplary multiple beam antenna 30a for receiving Internet data. The multiple beam antenna 30a is preferably a single ellipsoidal dish antenna with a major axis of approximately 24 to 30 inches. This allows

5   simultaneous reception from up to five different satellites that are within a 30-degree arc. Exemplary signals that may be communicated include a 43 watt PAS 3R signal, a 45 watt PAS 1 signal, a 74 watt SBS 6 signal, an 81 watt SATCOM K2 signal, an 87 watt GE 3 signal, and a 123 watt SBS 5 signal. These signals are processed by a synchronization, timing, compression and decoding circuit block 90. A personal

10   computer 92 may then be the source and/or destination of the Internet data.

The embodiment of FIG. 6 enables a reduced size and cost of the multiple beam antenna 30a and the related processing circuitry 90 by reducing the size of the amplifier by approximately one-third, at the expense of increasing the bandwidth required by approximately three times. Assume the multiple beam antenna 30a transmits to up to

15   three satellites, and assume the three uplink signals are processed in such a manner as to make them identical after they have been transponded through the satellite transponders and received at a downlink antenna. At the downlink antenna, which may be located at an Internet gateway, the signals are reconstituted into a signal whose signal-to-noise ratio (SNR) is approximately 4.77 dB greater than any one of the received signals.

20   Consequently, the EIRP of each of the channels transmitted from the multiple beam antenna 30a (also referred to as a virtual antenna) can be 4.77 dB less than would be required should a single channel be employed to receive the same signal power at the gateway antenna.

Specifically, assume N signals, which are exactly identical and perfectly

25   synchronized, are to be perfectly combined. The N identical signals of amplitude X add to form a signal with amplitude $N*X$. The N uncorrelated, random signals with identical statistical properties and equal root-mean-squared (RMS) amplitude Y add to form a random signal with RMS amplitude equal to $Y*sqrt(N)$. This process increases the SNR from X/Y to $[N*X]/[Y*sqrt(N)]$, yielding an improvement of sqrt(N) in the

amplitude domain. In the dB domain, the improvement is $20*\log_{10}(\text{sqrt}(N))$ or

$10*\log_{10}(N)$. For N=3, the improvement is 4.77 dB.

(TIMING)

5   In first, second, and third divider-combiner methods, tuners 32 provide

information to timing signal correlator 44 using one of two timing methods. In a first

timing method, receiver controller 42 adjusts tuners 32 to receive timing signal 23

placed on all satellites with transponders used by the virtual satellite system. In this

first method, tuner adjustment is necessary as the timing signals are placed at a

10   frequency assignment separate form the information-bearing transponder signal. This

out-of-band timing signal may be narrow-band in nature so as to conserve limited

bandwidth on the satellite and reduce system cost. In general, timing signal 23 is

unrelated to the information-bearing transponder signal in either information content,

modulation strategy, or data rate or frame rate in the case of digital transmission, but the

15   present invention is not so limited. The timing signal utilizes allocated bandwidth to

enhance the resolution of relative subchannel delay estimation. Possibilities for the

timing signals include pseudorandom noise, tone ranging, and time-dispersed pulse, but

the instant invention is not so limited. A good timing signal must have a strong sharp

cross-correlation with a time-shifted version of itself and have minimum spurious

20   correlations. The instant invention includes two timing signal processor methods. In a

first timing processor method, timing signal correlator 44 correlates output signals from

tuners 32 at various relative delays until an acceptable correlation occurs indicating that

the relative delay between the subchannels has been reproduced in timing correlator 44.

Receiver controller 42 then sets analog delays 72 in accord with this measured relative

25   delay to synchronize inputs to analog combiner 80. In the case that there are more than

two subchannels in the virtual satellite channel, timing signal processor 44 compares

subchannel signals pair-wise. In a second timing processor method, timing signal

correlator 44 correlates the output from each tuner 32 with a stored version of the

known timing signal, or by processing the recovered timing signal through a process

that will produce a periodic output in response to the timing signal. One example of such a process is a matched filter, but the present invention is not so limited. Once the delays 40, 56, 72 are adjusted to remove relative subchannel delay, tuners 32 are set to conduct the selected information-bearing transponder signals to the respective

5　demodulators in FIG. 1, FIG. 2, FIG. 3.

In a second timing method, the timing signal is as wide in bandwidth as the information-bearing transponder and resides in exactly the same bandwidth. In order to prevent distortion of the information signal, the timing signal is greatly attenuated. In order to recover the attenuated timing signal, timing signal correlator 44 first processes

10　the tuner outputs through a linear system that creates a large processing gain to amplify the expected timing signal above the output created by the presence of the uncorrelated information-bearing carrier. The instant invention may use one of three exemplary processes to recover a low-level in-band timing signal, but the present invention is not so limited. In a first exemplary process the timing signal is a time-dispersed pulse with

15　precise time dispersion introduced by a surface acoustic wave (SAW) filter in timing signal generator 23. A matching SAW filter in receiving terminal 16 performs the inverse of the dispersion process, thus recovering the primary timing signal which is a periodic narrow-time pulse. In a second exemplary process, the timing signal is pseudorandom noise. Timing signal processor 44 then applies spread spectrum

20　techniques to recover the timing of the low-level in-band timing signal. Upon timing signal acquisition, the correlated timing signal will experience a large process gain, but the uncorrelated information carrier will remain at the same relative level. This enables timing signal processor 44 to establish relative delay between subchannels, reporting results to receiver controller 42. A third exemplary timing process uses a multiple tone

25　signal to establish timing. The sine waves selected are harmonically related in such a way as to create a signal with a relatively long period, but giving good time resolution with the presence of some high frequencies. A linear filter at the selected frequencies recovers the timing signal in favor of the information carrier. Timing signal processor

44 then analyzes filtered timing signals to establish relative time delay between subchannels.

In the case of the digital content-division receiver of FIG. 2, there is typically no correlation between the subchannels to provide feedback as to the accuracy of the delay

5   settings of delays 40. This is a feed forward control system. Feedback is possible however in the exemplary systems of FIGS. 3 and 4. Outputs from delays 56 in the digital power-division receiver of FIG. 3 are highly correlated. If the delay setting is slightly in error, a local digital correle. on reveals the necessary small correction.

Outputs from delays 72 in the analog receiver of FIG. 4 are correlated to some extent

10   depending on the nature of the analog division and the instant properties of the analog content. This provides optional feedback to receiver controller 42 to affect local timing corrections.

While several particular forms and variations thereof have been illustrated and described, it will be apparent that various modifications can be made without departing

15   from the spirit and scope of the invention. Accordingly it is not intended that the invention be limited, except by the appended claims.